enters in any way into the exercise of this power, whatever the distance between the acting bodies, as that from the sun to the earth, or from star to star. We can hardly conceive of this force in one particle by itself; it is when two or more are present that we comprehend it: yet in gaining this idea we perceive no difference in the character of the power in the different particles; all of the same kind are *equal, mutual,* and *alike.* In the case of gravitation, no effect which sustains the idea of an independent or physical line of force is presented to us; and as far as we at present know, the line of gravitation is merely an ideal line representing the direction in which the power is exerted.

Take the Sun in relation to another force which it exerts upon the earth, namely, its illuminating or warming power. In this case rays (which are lines of force) pass across the intermediate space; but then we may affect these lines by different media applied to them in their course. We may alter their direction either by reflection or refraction; we may make them pursue curved or angular courses. We may cut them off at their origin and then search for and find them before they have attained their object. They have a relation to *time,* and occupy 8 minutes in coming from the sun to the earth: so that they may exist independently either of their source or their final home, and have in fact a clear distinct physical existence. They are in extreme contrast with the lines of gravitating power in this respect; as they are also in respect of their condition at their terminations. The two bodies terminating a line of gravitating force are alike in their actions in every respect, and so the line joining them has like relations in both directions. The two bodies at the terminals of a ray are utterly unlike in action; one is a source, the other a destroyer of the line; and the line itself has the relation of a stream flowing in one direction. In these two cases of gravity and radiation, the difference between an abstract and a physical line of force is immediately manifest.

Turning to the case of Static Electricity we find here attractions (and other actions) at a distance as in the former cases; but when we come to compare the attraction with that of gravity, very striking distinctions are presented which immediately affect the question of a physical line of force. In the first place, when we examine the bodies bounding or terminating the lines of attraction, we find them as before, mutually and equally concerned in the action; but they are not alike: on the contrary, though each is endued with a force which speaking generally is of the like nature, still they are in such contrast that their actions on a third body in a state like either of them are precisely the reverse of each other, — what the one attracts the other repels; and the force makes itself evident as one of those manifestations of power endued with a dual and antithetical condition. Now with all such dual powers, attraction cannot occur unless the two conditions of force are present and in face of each other through the lines of force. Another essential limitation is that

these two conditions must be exactly equal in amount, not merely to produce the effects of attraction, but in every other case ; for it is impossible so to arrange things that there shall be present or be evolved more electric power of the one kind than of the other. Another limitation is that they must be in physical relation to each other ; and that when a positive and a negative electrified surface are thus associated, we cannot cut off this relation except by transferring the forces of these surfaces to equal amounts of the contrary forces provided elsewhere. Another limitation is that the power is definite in amount. If a ball *a* be charged with 10 of positive electricity it may be made to act with that amount of power on another ball *b* charged with 10 of negative electricity ; but if 5 of its power be taken up by a third ball *c* charged with negative electricity, then it can only act with 5 of power on ball *a*, and that ball must find or evolve 5 of positive power elsewhere : this is quite unlike what occurs with gravity, a power that presents us with nothing dual in its character. Finally the electric force acts in curved lines. If a ball be electrified positively and insulated in the air, and a round metallic plate be placed about 12 or 15 inches off, facing it and uninsulated, the latter will be found, by the necessity mentioned above, in a negative condition ; but it is not negative only on the side facing the ball but on the other or outer face also, as may be shewn by a carrier applied there, or by a strip of gold or silver leaf hung against that outer face. Now the power affecting this face does not pass through the uninsulated plate, for the thinnest gold leaf is able to stop the inductive action, but round the edges of the face and therefore acts in curved lines. All these points indicate the existence of physical lines of electric force : — the absolutely essential relation of positive and negative surfaces to each other, and their dependence on each other contrasted with the known mobility of the forces, admit of no other conclusion. The action also in curved lines must depend upon a physical line of force. And there is a third important character of the force leading to the same result, namely, its affection by media having different specific inductive capacities.

When we pass to Dynamic Electricity the evidence of physical lines of force is far more patent. A voltaic battery, having its extremities connected by a conducting medium, has what has been expressively called a current of force running round the circuit, but this current is an axis of power having equal and contrary forces in opposite directions. It consists of lines of force which are compressed or expanded according to the transverse action of the conductor, which changes in direction with the form of the conductor, which are found in every part of the conductor, and can be taken out from any place by channels properly appointed for the purpose ; and nobody doubts that they are physical lines of force.

Finally as regards a Magnet, which is the object of the present discourse. A magnet presents a system of forces perfect in itself,

and able, therefore, to exist by its own mutual relations. It has the dual and antithetic character belonging to both static and dynamic electricity; and this is made manifest by what are called its polarities, *i. e.* by the opposite powers of like kind found at and towards its extremities. These powers are found to be absolutely equal to each other; one cannot be changed in any degree as to amount without an equal change of the other; and this is true when the opposite polarities of a magnet are not related to each other, but to the polarities of other magnets. The polarities, or the *northness* and *southness*, of a magnet are not only related to each other, through or within the magnet itself, but they are also related externally to opposite polarities, (in the manner of static electric induction) or they cannot exist; and this external relation involves and necessitates an exactly equal amount of the new opposite polarities to which those of the magnet are related. So that if the force of a magnet *a* is related to that of another magnet *b*, it cannot act on a third magnet *c* without being taken off from *b*, to an amount proportional to its action on *c*. The lines of magnetic force are shewn by the moving wire to exist both within and outside of the magnet; also they are shewn to be closed curves passing in one part of their course through the magnet; and the amount of those within the magnet at its equator is exactly equal in force to the amount in any section including the whole of those on the outside. The lines of force outside a magnet can be affected in their direction by the use of various media placed in their course. A magnet can in no way be procured having only one magnetism, or even the smallest excess of northness or southness one over the other. When the polarities of a magnet are not related externally to the forces of other magnets, then they are related to each other: *i. e.* the northness and southness of an isolated magnet are externally dependent on and sustained by each other.

Now all these facts, and many more, point to the existence of physical lines of force external to the magnets as well as within. They exist in curved as well as in straight lines; for if we conceive of an isolated straight bar magnet, or more especially of a round disc of steel magnetised regularly, so that its magnetic axis shall be in one diameter, it is evident that the polarities must be related to each other externally by curved lines of force; for no straight line can at the same time touch two points having northness and southness. Curved lines of force can, as I think, only consist with physical lines of force.

The phenomena exhibited by the moving wire confirm the same conclusion. As the wire moves across the lines of force, a current of electricity passes or tends to pass through it, there being no such current before the wire is moved. The wire when quiescent has no such current, and when it moves it need not pass into places where the magnetic force is greater or less. It may travel in such a course that if a magnetic needle were carried through the same course it would

be entirely unaffected magnetically, *i. e.* it would be a matter of absolute indifference to the needle whether it were moving or still. Matters may be so arranged that the wire when still shall have the same diamagnetic force as the medium surrounding the magnet, and so in no way cause disturbance of the lines of force passing through both; and yet when the wire moves, a current of electricity shall be generated in it. The mere fact of motion cannot have produced this current: there must have been a state or condition around the magnet and sustained by it, within the range of which the wire was placed; and this state shews the physical constitution of the lines of magnetic force.

What this state is or upon what it depends cannot as yet be declared. It may depend upon the ether, as a ray of light does, and an association has already been shewn between light and magnetism. It may depend upon a state of tension, or a state of vibration, or perhaps some other state analogous to the electric current, to which the magnetic forces are so intimately related. Whether it of necessity requires matter for its sustentation will depend upon what is understood by the term matter. If that is to be confined to ponderable or gravitating substances, then matter is not essential to the physical lines of magnetic force any more than to a ray of light or heat; but if in the assumption of an ether we admit it to be a species of matter, then the lines of force may depend upon some function of it. Experimentally mere space is magnetic; but then the idea of such mere space must include that of the ether, when one is talking on that belief; or if hereafter any other conception of the state or condition of space rise up, it must be admitted into the view of that, which just now in relation to experiment is called mere space. On the other hand it is, I think, an ascertained fact that ponderable matter is not essential to the existence of physical lines of magnetic force.

[M. F.]

In the Library were exhibited: —

Specimen of Auriferous Quartz, Nevada County, California, presented by F. Catherwood, Esq.

Portrait of Mr. Faraday, by G. Richmond, Esq.; and of Dr. Roxburgh, by J. Z. Bell, Esq.

Axe (Marked Stanislaus, 1661), and Ancient Mace. [Exhibited by H. W. Pickersgill, Esq., R.A.]

"Solitude," designed by J. Lawlor, Esq. and executed by the Messrs. Minton, for the Art-Union of London. [Exhibited by T. S. Watson, Esq., M.R.I.]

Specimens of Iron Ore from Northants and of Malachite, from Siberia;—Black Marble Vases. [Exhibited by Mr. Tennant.]

Specimens of Bookbinding, by Messrs. J. and J. Leightons.
Stereoscope and Talbotypes, by Mr. Newman.
Pseudoscope and Objects. [Exhibited by Messrs. Watkins and Hill.]
Gazine Lamp, burning Spirit from Peat, by Mr. Reece.
Minerals and Fossils. [Exhibited by Mr. Highley, jun.]
Specimens of Beet-Sugar from Paris. [Exhibited by Mr. Duer.]
Painting, &c. on China. [Exhibited by W. Copeland, Esq.]
Specimens of Lead and Copper Ores, from Wales. [Exhibited by F. Lloyd, Esq., M.R.I.]
Flamingo, White Woodcock and Marmozets, mounted by Messrs. Leadbeaters.
Testimonial to Dr. Jeremie (in silver). [Exhibited by Messrs. Hunt and Roskell.]
Fish, Electrotyped from Nature, by Mr. J. How.
Talbotypes — Views in Edinburgh and Paris, Landscapes, &c. [Exhibited by Mr. Henneman.]
Specimens of Aloine. [Exhibited by T. N. R. Morson, Esq., M.R.I.]
Specimens of Work in Silver and Electrotype by Messrs. Elkingtons.
Model in white marble of the Memorial Pillar about to be erected at Ammerdown Park, Somerset, by Col. Jolliffe. [Exhibited by J. Jopling, Esq., the Architect.]
Mr. Varley exhibited by the Microscope Snails' eggs, the heart beating — Wheel Animalcules — Circulation of blood and peristaltic motion in small worms, and the circulation of sap in the Nitella.
Model of Richardson's Tubular Life-boat. [Exhibited by W. Varlo Hellyer, Esq., M.R.I.]

The Inventor, H. T. Richardson, Esq., in a paper accompanying the Model, stated that "the Tubular Life-boat cannot upset, sink or be water-logged, can beach through a heavy surf on any sandy or shingle shore, and pull off again without the aid of anchors; steers, rows, and sails well. Its extra buoyancy is six tons, exclusive of its own weight, which is within two;—it rows sixteen oars, and carries two lug sails, a jib and top sails—and can row and sail at the same time. In construction it is totally different from all other boats, being formed of two metal tubes forty feet in length, by two and a half diameter, tapering at either end in a manner so as to give the appearance of sheer. An iron frame-work securely rivetted unites the whole into one complete mass, the tubes having longitudinal bars of iron and hoops within, and iron keels running from end to end. They are divided into water-tight compartments, have air-proof bags in the four corners, and the two middle are filled with cork; a cork fender also surrounds the whole fabric. The rowers and passengers are placed on a platform above the frame-work, which is surmounted by a light gunwale the height of the row-locks; a rope passes along under the keelson for the purpose of towing."

GENERAL MONTHLY MEETING,

Monday, July 5,

SIR CHARLES FELLOWS, Vice President, in the Chair.

Charles Blakely Brown, M.D. Edwin Lankester, M.D. F.R.S.
David Oldfield, Esq. F.L.S. &c.

were *admitted* Members of the Royal Institution.

Sir George Pollock, G.C.B. Lieut.-Gen. in Hon. East India Company's Service

was duly *elected* a Member of the Royal Institution.

The Presents received since the last Meeting were laid on the Table and the thanks of the Members returned for the same.

FROM

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